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THE PETROGRAPHIC CHARACTER OF OHIO SANDS WITH RELATION TO THEIR ORIGIN[1]

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In connection with a report in preparation by the Geological Survey of Ohio on glass and molding sand, a petrographic examination of a large number of samples was made by the writer of this paper. The samples were collected from all parts of Ohio and represent practically all the important deposits of the state from the oldest to the very recent. About ninety rock samples, Carboniferous and older, were examined, and forty uncemented, recent sands from the glacial drift and other sources. The petrographic work was done in the geological laboratories at Columbia University.

In preparing the samples for inspection with the microscope, thin sections were made of the rocks. Most of these had only a slight bond so they were first boiled in Canada balsam until all the interstices were permeated by that liquid. On cooling there resulted a firmly cemented mass which would permit of grinding to the usual thickness. In the case of loose, uncemented sands, liquid mounts were made in oil of cloves which has an index refraction similar to that of balsam. Many of the samples being made up of grains too thick for study with polarized light were first crushed to 100-mesh size in an agate mortar, after a preliminary inspection had been made to determine the shape and size of grain.

The sands ordinarily met with in Ohio may be divided into three great groups on the basis of physical properties and mineral make-up. The three groups are: (1) The old sandstone formations Permo-Carboniferous and older; (2) residuary and outwash deposits derived by weathering and erosion of the sandstones; (3) glacial drift sands—recent deposits made up of assorted material obtained from the drift by the action of wind and water currents. Each group has certain physical and mineralogical features which are quite characteristic of the sand wherever found and which will be described.

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[1] Published with permission of the State Geologist of Ohio.

The old sandstones of Group 1 are made up of travel-rounded grains cemented more or less firmly by silica, limonite, hematite, or some other bond. Quartz is by far the most abundant mineral. The accessory constituents seldom make as much as 15 per cent of the sand. They are minerals of a rather stable nature together with secondary products derived from the decompositon of the less stable original minerals. Orthoclase and plagioclase are as a rule much decomposed and their presence is shown by aggregates of sericite, kaolinite, and secondary quartz. Occasionally plagioclase grains are seen which still show twinning lines. Microcline is almost invariably fresh and unaltered. Tourmaline is common. Muscovite is widely distributed, being found in nearly every sand, but biotite is rare. Amphibole and pyroxene are almost entirely altered to chlorite, limonite, and other secondary products. No garnet was found in any of the sandstone samples. A sand from the Sharon Conglomerate of Summit County is regarded as representative of the group and its mineral list follows. The minerals are listed in order of abundance.

1. Quartz
2. Muscovite
3. Kaolinite
4. Microcline
5. Zircon
6. Limonite
7. Orthoclase
8. Plagioclase
9. Sericite
10. Hematite
11. Apatite
12. Chlorite
13. Rutile

There is a slight bond of sericitic kaolinite and limonite. Some of the quartz grains show slight secondary growth. The feldspars are almost entirely altered and their outline is preserved by aggregates of sericite, kaolinite, and secondary quartz which are so interlocked as to resemble a mosaic pattern.

The Sylvania (Silurian) formation of northwestern Ohio is a good illustration of a very pure sand having few accessory minerals. A sample from Lucas County was found to contain only quartz, calcite, dolomite, rutile, and apatite. The calcite and dolomite occur as minute rhombohedrons which serve as a cementing material. The rutile and apatite are needle-like inclusions in the quartz. The quartz grains average about 0.3 mm. in diameter and are nearly spherical in outline. A chemical analysis shows 95.11 per cent of silica.

There is a number of secondary minerals which have found place in the old sandstones of Ohio subsequent to their deposition. Some of these have resulted from decomposition in place of original minerals while others have been brought in from foreign sources and precipitated from solution. Some of the secondary minerals due to precipitation from solution are: secondary quartz, hematite, limonite, calcite, dolomite, siderite, pyrite, and marcasite. Some of the alteration products of original minerals are: kaolinite, sericite, chlorite, secondary quartz, leucoxene, limonite, and hematite.

The sands of Group 2, derived by weathering and erosion of the old sandstones, are usually loose, uncemented deposits that occur as a residuary mantle on the upland or as bar deposits along ancient and modern valleys. Such sands may be made up of rather angular grains, especially if there was silicification of the sandstone whose weathering furnished the material. A coating of iron oxide on the grains is quite characteristic. This may be so thick as entirely to conceal the interference colors of the quartz when viewed under crossed nicols. The minerals of residual sands are fewer than those in the original sandstone. Solution and erosion incident to weathering eliminate many of the accessory constituents and as a result minerals other than quartz and limonite are few. Such materials when favorably situated might be reworked by wind and water currents to form very pure quartz sand deposits comparable with the Sylvania.

So much of Ohio is covered by glacial drift that most of the modern river sands are a mixture of contributions from local sources and from the drift. There are, however, a few counties in the southeastern part of the state which have sand deposits obtained entirely from local sandstones with no contributions from the glacial drift. These deposits are found along both modern and pre-Glacial drainage channels. In Gallia County is an ancient, abandoned valley which forms a prominent topographic feature and has been traced for many miles by Tight,[1] who has named it the Marietta River. A sand sample taken from a bar deposit in this valley has the following mineral make-up: quartz, limonite, zircon, tourmaline, apatite, and kaolinite. All of the grains are thickly coated with limonite.

The sands of Group 3, derived by assortment of the Glacial drift, are usually of a very heterogeneous nature both as to shape of grain and mineral composition. There are sharp, angular particles with freshly fractured surfaces that have evidently resulted from the crushing and granulation of rock masses. There are also well-rounded grains that represent sand deposits in the path of the advancing ice front which were carried along and blended with the comminuted rock material. During the recession of the ice and subsequently, wind and water currents have assorted much of the drift into gravels, sands, and silts. In the northern part of the state are fine-grained sands and silts that have been deposited in the shallow waters of recessional lakes. These sands are remarkably well assorted. Extensive deposits in Erie County are found suitable for molding sands. In one sample the diameter of grain was found to range between 0.3 and 0.06 mm. with 0.1 mm. as an average. Only the largest grains show any rounding. Another sample was made up of sharp grains ranging from 0.05 mm. down to mineral flour.

As to mineral content the glacial drift sand is quite distinct from the preceding groups. Quartz is still the most abundant mineral, but there is almost always a high percentage of accessory minerals. Many of these are of a perishable nature and cannot withstand solution and decomposition incident to long weathering. Outcrops of crystalline metamorphic rocks beyond the Great Lakes may be regarded as the source of such minerals. Probably 90 per cent of the drift in any one locality is made up of materials derived from within fifty miles of that point but there is quite invariably a portion which, by its mineral content, shows derivation from the crystalline rocks. A number of minerals entirely wanting in the old sandstones are found fresh and little altered. Garnet, diopside, augite, enstatite, hypersthene, hornblende, actinolite, cyanite, and free grains of magnetite are abundant in the drift. Of these garnet, diopside, augite, enstatite, hypersthene, and cyanite are not found in the old sandstones and the others are rare. The former presence of abundant ferromagnesian minerals is indicated by chlorite, saussurite, and other alteration products.

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[1] W. G. Tight, "Drainage modifications in southeastern Ohio and adjacent parts of West Virginia and Kentucky," *Professional Paper U.S. Geol. Surv. No. 13*, p. 76; also Plate XI.

The character of the glacial sand type is well shown by a fine-grained sand from near Sandusky, Ohio. The bed is regarded as an off-shore deposit in Lake Warren.[1]

MINERALS IN ORDER OF ABUNDANCE

1. Quartz
2. Garnet
3. Diopside
4. Hornblende
5. Enstatite
6. Microcline
7. Plagioclase
8. Orthoclase
9. Hypersthene
10. Tourmaline
11. Zircon
12. Limonite
13. Kaolinite
14. Apatite
15. Sericite
16. Epidote
17. Magnetite
18. Rutile

The sand is made up of angular grains with surfaces that show recent fracture. The size grades from 0.05 mm. diameter down to mineral dust. There is little limonite coating on the grains. Garnet, diopside, enstatite, hypersthene, hornblende, and feldspars are the principal accessory minerals and none of these are much decomposed.

The characters of the three great sand types may be summarized as follows: The rock sands (all Paleozoic) are made up of travel-rounded grains more or less firmly cemented. The minerals are those of a stable nature together with some which have been derived by the alteration of less stable original minerals. Ferromagnesian minerals are almost entirely wanting. The residual sands and outwash deposits derived from erosion of the sandstones are made up of products that represent the final results of weathering. Many minerals present in the sandstones have been eliminated and there remains little besides the quartz, which is itself usually heavily coated with limonite. The glacial drift sand is a hodgepodge mixture of anything that happened to be in the path of the ice. Travel-rounded grains derived from sand deposits are mixed with sharp particles produced by the comminution of rock. Minerals of an unstable nature recently derived from the crystalline rocks are abundant and these show little alteration.

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[1] Frank Leverett, Monograph 41, *U.S. Geol. Surv.*, Plate XXII.

MINERAL SUMMARY

Thirty-four minerals have been recognized in Ohio sands. Some of these are abundant in practically every sample while others are less widely distributed and are only present in small amounts. While the samples were taken from all parts of the state from sands of all ages they can hardly be regarded as representative of many of the formations because only those outcrops which appeared suitable for glass or molding were sampled. A list of the minerals is given with notes as to the occurrence of each.

MINERALS OF OHIO SANDS

Quartz
Orthoclase
Plagioclase
Microcline
Hornblende
Actinolite
Diopside
Augite
Enstatite
Hypersthene
Muscovite
Sericite
Tourmaline
Zircon
Apatite
Rutile
Biotite
Garnet
Corundum
Magnetite
Ilmenite
Leucoxene
Titanite
Monazite
Xenotime
Hematite
Limonite
Kaolinite
Chlorite
Serpentine
Epidote
Calcite
Dolomite
Pyrite

Quartz.—Quartz is by far the most abundant mineral in all sands examined. It usually constitutes over 90 per cent of the make-up of the old sandstones. Only twelve out of ninety-one samples examined contained less than 90 per cent of quartz. The most impure sandstone inspected had about 75 per cent. The purest sand on analysis showed a little more than 98 per cent of quartz.

Quartz is also the principal mineral in sands selected for molding purposes but in some cases it is slightly less than the sum of all the accessory minerals. In glacial drift sands it usually ranges from 50 to 70 per cent. It may constitute as much as 90 per cent of residual sands derived from weathering of the sandstones.

Feldspars.—Feldspars probably rank next to quartz in abundance and distribution. About three-fourths of the sandstone samples have feldspar. Plagioclase was recognized in one-fourth of the rock samples and orthoclase in one-fifth. Both are almost invariably much decomposed and in many cases can only be called "much-altered feldspar" without closer identification. Microcline is present in more than one-half of the samples and is one of the principal accessory minerals. It shows little decomposition even in the oldest sandstones. In the most arkosic sandstones of Ohio the feldspar content is usually less than 10 per cent.

The glacial drift sands have a large percentage of feldspar. This may be as much as 25 per cent in some cases. Orthoclase and plagioclase showing little or no decomposition are common. These minerals are entirely wanting in the residual sands but microcline is occasionally found.

Amphibole.—Hornblende and actinolite, the common varieties of amphibole, are almost entirely limited to the recent sands. Nearly every glacial drift sand contains actinolite and a lesser amount of hornblende. A few of the sandstones have much decomposed remnants of what appears to be actinolite. That these minerals were formerly present in many of the sandstones is shown by chlorite and other alteration products.

Pyroxene.—The common varieties of pyroxene in sands are diopside, enstatite, and hypersthene. Augite is less common. All are limited to recent sands of glacial drift origin. No pyroxene was seen in the sandstones but its former presence is indicated by alteration products.

Mica.—Muscovite flakes visible without a microscope are present in about two-thirds of the sandstone samples and one-half of the uncemented sands. Sericite is a common product from the alteration of feldspars. Biotite is rare even in the glacial drift sands.

Tourmaline.—This is very widely distributed. It was found in nearly three-fourths of the samples examined.

Zircon.—Zircon is nearly always present. It was found in over four-fifths of the samples.

Apatite.—About one-half of the samples were found to contain apatite. Both inclusions and free grains are common.

Rutile.—Nearly every sand has a small amount of rutile. Microscopic hairlike inclusions in quartz and free grains are the modes of occurrence.

Garnet.—Garnet is one of the principal accessory minerals of glacial drift sands. It was not found in any of the sandstones or residual sands.

Corundum.—Corundum is occasionally found in sands of all ages.

Magnetite.—More or less magnetite is always present. It is found both as free grains and inclusions in other minerals. In the glacial drift sands it is a prominent constituent.

Ilmenite and leucoxene.—Ilmenite is sometimes mixed with magnetite. Its presence is shown by leucoxene, an alteration product.

Titanite.—Titanite is occasionally seen in the recent sands of glacial drift origin.

Monazite.—Monazite is sparingly distributed in very small amounts in Ohio sands. It was noticed in three recent sands and seven sandstones.

Xenotime.—Xenotime is occasionally found in small amounts in sandstones near the base of the Coal Measures and in residual sands derived from these. It was noticed in twenty-two rock samples most of which were taken from the Sharon Conglomerate.

Hematite.—Hematite is quite common as inclusions in quartz. Earthy red hematite is sometimes a cementing material in sandstones.

Limonite.—Limonite is always present. It is a common cementing material in sandstones. In most of the sandstones examined the limonite content is less than 2 per cent. The grains of residual sands are usually thickly coated with limonite.

Kaolinite.—Kaolinite is a prominent constituent of most sands. In feldspathic sandstones it may constitute several per cent of the make-up.

Chlorite, serpentine, epidote.—These are of common occurrence in the Carboniferous sandstones. They are largely responsible for the greenish and bluish colors so often seen in those rocks.

Calcite and dolomite.—These were found as cementing material in the Sylvania sandstone of northwestern Ohio. Slight amounts, probably comminuted limestone, are sometimes seen in the glacial drift sands.

Pyrite.—No pyrite was seen in the sand samples but small limonite stained cavities probably due to oxidation of pyrite were seen in one sandstone. It is common in the deeper workings of quarries.

One of the interesting features brought out by the investigation is the entire absence of garnet in the old sandstones of Ohio. Inquiry and personal search show that this is not a local condition but that the scarcity or absence of garnet in the older sandstones is prevalent in widely separated regions. The West Virginia Geological Survey has recently made a petrographic examination of about thirty sandstones and garnet was found in only one of these—a sample from the Dunkard series.[1] Dr. A. A. Julien, whose study of sands has been very extensive, writes: "The

[1] G. P. Grimsley, "Iron Ores, Salt and Sandstone" *West Virginia Geol. Surv.*, IV (1909), 447.

scarcity or absence of garnet in the older sandstones generally prevails, I think, in all regions. I first recognized this in the Carbonic sandstones of Great Britain and soon afterward in those of Arabia Petræa and of northern Africa. It is also markedly absent or rare in the St. Peter, Cambrian, and older quartzites of this country."

In order to obtain data as to the occurrence of garnet in the older sandstones of eastern North America, a number of rock samples were examined. These were taken from collections of the Geological Department of Columbia University, and represent most of the important sandstones of the Paleozoic of the Appalachian region. There follows a summary of the results:

Cambrian: (1) Etcheminian conglomerate, Hanford Brook, Nova Scotia. Zircon present. No garnet seen. (2) Feldspathic quartzite, contact with pre-Cambrian. Doe River, Tenn. Zircon, tourmaline, and microcline seen. No garnet. (3) Sandstone, Iron Mountain, Mo. Plagioclase and zircon found, also a few grains of garnet.

Ordovician: St. Peter sandstone, Iowa. No garnet.

Silurian: Sylvania sandstone, southern Michigan and northwestern Ohio. No garnet.

Devonian: (1) Oriskany sandstone, Huntington, Pa. Zircon, tourmaline, and plagioclase (little decomposed). No garnet. (2) Oriskany sandstone, Vienna, Ontario County, N.Y. Zircon and calcite. No garnet. (3) Catskill sandstone, Monkey Hill, Delaware County, N.Y. Zircon and tourmaline. No garnet. (4) Catskill sandstone, Mill Creek, Pa. Tourmaline and zircon. No garnet. (5) Catskill sandstone, Catskill Mountains. A large number of thin sections were examined. Quartzite pebbles were seen, showing that the formation was derived in part from the reworking of a previous sandstone. Considerable well-preserved feldspar, and much epidote and chlorite are present. No garnet was seen.

Carboniferous: (1) Pocono sandstone, Dungannon, Pa. Zircon, tourmaline, and titanite present. One grain of garnet was seen. It had a pitted surface as though affected by solution. (2) Pocono, Pottsville, Pa. Zircon and tourmaline. No garnet. (3) Mauch Chunk sandstone, Cave Gorge, Dungannon, Pa. Zircon, plagioclase, tourmaline. No garnet.

As was mentioned in a previous page, garnet was found in one sample from the Permian of West Virginia. The Triassic beds of New Jersey and Connecticut abound in garnet. The grains are always fresh appearing with little sign of solution or alteration.

In attempting to account for the scarcity or absence of garnet in the older sandstones, these questions arise: Is it due to the inability of garnet to withstand solution and decomposition incident to weathering? Is garnet sufficiently resistant to the wear of travel to find a place in sands laid down at a distance from the source of supply? Or is the scarcity due to the derivation of the components of the sandstone from a region where garnet was not an important rock-forming mineral?

There is ample evidence that garnet is quite resistant to ordinary weathering processes. It is a common constituent of residuary sands derived from decomposed schists. The Newark series of New Jersey and Connecticut, consisting largely of coarse sandstone which would favor free circulation of ground waters, has been exposed to weathering processes for many ages; nevertheless it contains abundant garnet grains which show little evidence of solution or alteration. Furthermore the discovery of occasional particles in a few of the older Paleozoic sandstones is still stronger proof of the resistant properties of garnet. The scarcity cannot be due to mere decay since often other minerals survive which are equally or more susceptible to decay, such as feldspars and mica.

The physical properties of garnet are such that it should withstand the wear of long travel. Lack of cleavage, and hardness are in its favor. Zircon, tourmaline, feldspars, and other minerals which are somewhat similar in their physical properties to garnet are widely distributed even in the very old sandstones.

This leads to the conclusion that the materials of the older sandstones were derived from sources where garnet was not abundant. Repeated reworking of successive sandstones has doubtless furnished much of the material. Very pure quartz sands of the Sylvania type are probably entirely derived in that way. However, most of the great sandstone formations have constituents which have certainly come rather directly from crystalline areas. This is especially true of the Catskill series and the "Coal Measures" sandstones.

Garnet is a characteristic mineral of regional and contact metamorphism. It is common in gneisses and schists of sedimentary origin. As an original mineral in igneous rocks it is much less common. The gneisses and schists of the Appalachian region are abundantly provided with garnet. Glacial drift drawn from such sources has so much of the mineral that it is second only to quartz in abundance. The Triassic beds of the east, fairly reeking with garnet, furnish an illustration of a sandstone built largely from materials derived rather directly from the crystallines. Conditions of sedimentation during "Coal Measures," Mauch Chunk, and Catskill time were probably not greatly different from those that prevailed during the formation of the Triassic beds. All are either continental or near shore in origin.

To the writer it seems that the difference in mineral content between the Triassic and the older sandstones indicates a quite different source of material. While it is obvious that gneisses and schists contributed very extensively to the Triassic beds, it seems probable that such rocks did not furnish much of the materials of the older sandstones. A large portion of these have doubtless come from crystalline sources, but the minerals indicate that the rock may have been igneous rather than metamorphic. It is conceivable that a peridotite or gabbro furnished the ferromagnesian minerals so abundant in the Catskill series, while a granite was the source of the zircon, tourmaline, and muscovite of the "Coal Measures" sandstones.

It is becoming more and more evident to geologists that the mountain-making processes which took place at the close of the Paleozoic were accompanied by the intrusion of extensive igneous masses and the metamorphism of the country rock into schists. The work of Loughlin[1] and others has demonstrated the magnitude of these changes in Rhode Island. A number of intrusive masses, mostly granite, in the highland region of New York and New Jersey, are known to be post-Ordovician and may be of the same age as those in Rhode Island. Recently a report has come from Virginia of the finding of fossils in schistose slates of the Piedmont belt. These slates were formerly regarded as pre-Cambrian but the fossils show them to be Upper Ordovician in age.[2] Thus it is seen that as more detailed work is done in the region of the crystalline rocks, more and more of the "Complex" is differentiated and removed from the pre-Cambrian and proved to be more recent.

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[1] G. F. Loughlin, "Intrusive Granites and Associated Metamorphic Sediments in Southwestern Rhode Island," *Am. Jour. Sci.*, XXIX (1910), 447–57.

[2] Thomas L. Watson and S. L. Powell, "Fossil Evidence of the Age of the Virginia Piedmont Slates," *Am. Jour. Sci.*, XXXI (1911), 33–44.

Is it not possible that the general scarcity of garnet in the older sandstones may be due to the more recent formation of many garnetiferous schists which are now classed as pre-Cambrian?